DOCUMENT RESUME

ED 223 424 SE 039 581

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TITLE The Evolution of College General Biology: From the Sixties to the Present.
PUB DATE May 82
NOTE 63p.; A report presented to the Faculty of the School of Education, San Diego State University, CA.
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Biology; *College Science; *Educational Trends; Higher Education; *Introductory Courses; Majors (Students); Nonmajors; *Science Curriculum; Science Education; *Science Education History; Science Instruction; Teaching Methods

ABSTRACT

Since the early sixties, general/introductory biology courses have evolved as a consequence of a multitude of forces which have been changing the face of our society. These forces are, in turn, consequences of a much greater phenomenon, the Scientific Revolution. Shortages of scientific personnel and the national fervor generated by the space race, the promotion of scientific literacy in education, the accelerating development of molecular and cellular biology, a demand for quality of life over quantity of material goods expressed in the mid-sixties, and a demand for relevance (in particular that science address world problems and that science education meet individual needs) are only some of the factors that contributed to curriculum development and revision during the last two decades. As a result, there has been a considerable proliferation of instructional strategies and course organization schemes. General/introductory courses were the beneficiaries of many of the products of teaching technology, the development of which was accelerated as a consequence of the Scientific Revolution. In response to greater individualization, such techniques as mastery learning and audio-tutorial instruction have been employed in general/introductory biology courses. However, because of declining enrollments, non-majors are comprising a larger proportion of these courses and their needs must be met by future educational advances. (Author/JN)

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THE EVOLUTION OF COLLEGE GENERAL BIOLOGY: FROM THE SIXTIES TO THE PRESENT

A Report
Presented to
The Faculty of the School of Education
San Diego State University

In Partial Fulfillment
of the Requirements for the Course
Education 795A Seminar
Dr. C. E. Fishburn, Professor

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by
Charles Robert Wert
May 1982

CHAPTER ONE

Introduction

Traditionally, a course in general biology has been assigned an important role in undergraduate curriculum. Currently, as a general education course it is intended to provide learning that:

1. Builds skills for advanced studies and lifelong learning.
2. Distributes time available for learning in such a way as to expose students to the mainstream of thought and interpretation . . .
3. Integrates learning in ways that cultivate the student's broad understanding and ability to think about a large and complex subject (Carnegie, 1977, p. 165).

"General education has been regarded as a 'base' or 'foundation' on which is built a field of specialization . . ." (Gaff, 1980, p. 4). General biology was thought to have served this purpose by being an axial point for students majoring in some aspect of the natural sciences. In a general biology course, these students have traditionally been exposed to a broad range of topics in biology, with the purpose of providing the students with the knowledge, understanding and experience on which to base decisions concerning their academic pursuits and professional goals.

A general biology course was thought to serve non-biology majors by exposing them "to the mainstreams of thought and interpretation . . . [in biology]" (Carnegie, 1977, p. 165). Certainly, the validity of such a purpose is obvious when one considers the tremendous impact technology has had and will most certainly continue to have on their lives as members of this society. Sawhill (1980) observed:

> With each passing year, it seems that the social and ethical issues that scientific advance forces us to confront become more numerous. Though many people do not know it, we are living in the midst of a biological revolution (p. 20).

If, as members of an increasingly technological society, students are going to exercise any measure of positive influence with respect to such issues as

- endangered environmental quality,
- nuclear, chemical and biological warfare,
- disproportionate exploitation and distribution of resources,
- overpopulation and population control,
- abortion, euthanasia and related issues,
- genetic engineering, etc.

then they will first have to make decisions concerning those issues. It is vital that those decisions be grounded in a sound educational base (Jastrow, 1966; and, Richter, 1978). Hiden T. Cox (1966) summarized it beautifully in his statement, "A scientifically literate public isn't . . .

just desirable, it's essential" (p. 37).

General biology has also been an opportunity for students (biology and non-biology majors alike) to acquire skills in observation, critical thinking and experimental technique. Certainly, these skills are essential to the academic and professional success of biology students; however, one or more of these skills are invaluable tools for the future of any student (Richter, 1978).

Finally, besides an opportunity "to increase the student's knowledge" of biology, a general biology course is also an opportunity "to increase favorable attitudes toward the subject" (Garcia and McFeeley, 1978, p. 2). With the ever-increasing technology, and the increasing stress it imposes on society, general biology offers a source of important social lubricant to ease the friction between the biological community and the lay community (Jastrow, 1966; and, Hodgson, 1970).

Statement of the Problem

The relevancy of general biology as a general education course would seem indisputable then. However, since the 1960's, the topic of general education itself has been a hotbed of controversy. Gaff (1980) observed:

> It is no longer news that general education is in disarray. More than two years have elapsed since the Carnegie Foundation for the Advancement of

> teaching declared that "general education is a disaster area," and since the faculty at Harvard University began debating the report of its Task Force on the Core Curriculum (p. 1).

Considering the numerous controversies surrounding general education (Baker, 1967; Carnegie, 1977; Fincher, 1978; Ritcher, 1978; Gaff, 1980; and, Kridel, 1980), and the pressures for curriculum reform (Eiss, 1966b; Hudson and Smith, 1976; Bybee, 1977; and, Sawhill, 1980), the question naturally arises:

> Has college general biology undergone change in purpose and/or content since the "sixties?"

If there has been change in general biology courses:

> In what directions have they evolved?

and

> What are the circumstances surrounding the evolution of general biology, including the forces generating the change?

CHAPTER TWO

Review of the Literature

General Background

In October of 1957, the U.S.S.R. successfully put into orbit the first man-made satellite, initiating the "space race." An explosion growth in technology followed in this country, immediately resulting in an enormous shortage of scientists, engineers and high technology craftsmen. The vacuum of talent of the early sixties brought pressure to bear on the American educational system to supply that needed talent, and precipitated in a "period of curriculum revision and teacher training that was the largest in our history" (Bybee, 1977, p. 339).

In a 1964 conference report, Thomas Hall (et al.) observed that many American colleges and universities were reorganizing undergraduate biology curricula. The greatest impetus, by far, in the sixties and early seventies was provided by what Hilberry (1966) refers to as the "Scientific Revolution" (p. 26). Hilberry describes the Scientific Revolution as "sweeping on and in an ever-swelling tide and every inhabitant of our world, however remote he may seem to be from science itself, is being

borne into a new and uncharted future on its flood of material, or intellectual, and yes spiritual accomplishments" (p. 26).

In response to this revolution, Hilberry proposed that the main goal of practitioners and teachers of science is to transmit to following generations "the essence of the Scientific Revolution; the ability to think logically and objectively as well as to know, to synthesize as well as to analyze, to dwell in the world of abstract as well as to inhabit the familiar earth with effectiveness" (1966, p. 26). The promotion of "scientific literacy" (Cox, 1966; DuBridge, 1966; and, Butler, 1968) is still a primary goal of science education today.

One of the most important consequences of the emphasis on scientific literacy was that of the scientific community giving more attention to the needs of the nonscience major. Strassenburg (1966) observed that, "[at] long last, scientists are now writing materials for science courses designed especially for the nonscience major and contributing to the teaching of these courses" (p. 40). Consequently, general education received more attention in science education. This new importance is symbolized by Strassenburg's proposal of "two guidelines for teaching general courses in science" (p. 39):

> The first is that general education students of science should not be mixed in the classroom with students who do plan to apply their scientific training to their specific goal of becoming scientists.

His second suggestion is as follows:

> Again, I remind you that my chosen definition says that general education should be limited to study not designed for precise application, and I believe this also says we should not design science courses exclusively for prospective teachers.

Strassenburg (1966) noted in a speech given at a National Science Teachers Association conference, that science courses for nonscience majors have been available for years. He pointed out, though, that until the mid-1960's "research scientists showed no interest in teacher training and cared little about the scientific literacy of the general population" (1966, p. 40). However, with the advent of the post-sputnik era, the scientific and technological communities soon realized that advances in their respective fields were (and are) dependent on the broad support of the government and hence the general population. The layperson's knowledge and perception of science subsequently became a driving concern of research scientists (Strassenburg, 1966; Olson, 1969; and, Frosch, 1973).

One of the earliest descriptions of post-sputnik general education science courses appears in a conference report entitled, "Problems of Science in General Education" (in Viewpoints on Undergraduate College Science Programs,

Eiss, 1966b). The "[n]ature of the [c]ourse" is described as follows:

> All aspects of the science course, including curricular development, the instructional methods used, the classroom atmosphere, the nature of the laboratory studies, and the evaluation procedures used, should emanate and derive their validity from course objectives. These course objectives, in turn, should be expressed in behavioral terms and should concern themselves with the implementation of the kinds of activities that constitute science, . . .
>
> The general education course should not be regarded as a service course or as a foundational course to the other sciences. It should not be a course in science. It should be exploratory in nature and should involve the student in scientific activity in the laboratory. Lecture, films, discussion, and evaluation should all help give direction to the course. Although there is no traditional body of standard content as such which must be "covered" in such a course, students who have not yet declared a major should be afforded the opportunity to become acquainted with the field of science, not just the first course in one area of science.
>
> A high quality general education course can profitably be taken by all students, including science majors. It gives them an overview of the field of science and some insights into the nature and structure of science that they often do not get in the beginning specialized course, where the major preoccupation is "covering" the subject matter. However, if all students are required to take the general education science course, much flexibility should be provided in the form of honors sections (enriched), opportunity for acceleration or waiver by examination, special sections for slower learners and/or repeaters who have previously failed the course, as well as for those with poor backgrounds in science (pp. 42-45).

The essential elements of this description of a general education science course appears in another report, "General Education" (in Science Education in the Junior College, Problems and Practices, Eiss, 1966a). Also listed in that report is a list of course objectives for science courses

in general education for nonscience majors:

> To help students see and comprehend the scientific phenomena about them.
>
> To show how scientists arrive at their views and to instill in students the means of applying these methods to daily problem solving, questioning, and inquiry.
>
> To recognize the basic unity of science by introducing interdisciplinary approaches whenever possible.
>
> To show and to develop an appreciation for the esthetic values inherent in the field of science.

In the same previously mentioned address, Strassenburg (1966) issued a plea for the recognition of the importance of the laboratory experience to the general education science course. He expressed a deep concern over an apparent trend of "abandoning laboratory entirely in courses for nonscience majors" (1966, p. 40). He reasons further:

> It is not primarily a knowledge of scientific facts we wish our students to learn. Rather we wish to transmit to them an appreciation of the processes of inquiry, observation, abstraction, analysis, and prediction by which scientists organize man's understanding of nature. Since the entire chain is anchored in the phenomena it attempts to interpret, it is difficult to see how a program which fails to provide the student with an opportunity to stimulate his own curiosity by direct observation could convey a realistic impression of the scientific enterprise (pp. 40-41).

Similar statements were made in the above-mentioned report, "General Education" and its companion report, "Summary of Discussion Groups: The Preparation of Science Majors" (in Science Education in the Junior College, Problems and Practices, Eiss, 1966a). The discussion

groups also indicated a move away from emphasis on factual information and a trend toward emphasis on principles and key ideas . . . " (p. 64), thus supporting Strassenburg's contentions. Frosch (1973) explains that this trend in college general science was a response to the revised elementary and secondary science curricula. With each passing year, children were receiving more fundamental information in elementary and secondary science classes. Thus, colleges were pressured to present more conceptual information in their general science classes.

In "Preparation of Science Majors," the problem of meeting the needs of entering freshmen with widely divergent backgrounds was discussed at length. Certainly, the efforts of the Stanford Colloquium participants were in response to the "advent of universal access to higher education" (Carnegie, 1977, p. 5). "Recommendations varied from the possibility of eliminating the introductory course entirely through advanced placement for capable students to providing an introductory course that might remedy common deficiencies of high school students, including introduction of new course materials at the commencing level and the introduction of research-oriented problems into laboratory work" (Eiss, 1966a, p. 64). In "Problems of Students With Poor Backgrounds" (in Science Education in the Junior College, Problem and Practices, Eiss, 1966a), the

importance of well-defined background requirements was stated, particularly emphasizing reading and mathematics skills. The importance of mathematics was also mentioned in "Problems of Science in General Education." The first report also seemed to imply a direct correlation between the level of the content of a general science course and the sophistication of required mathematics skills.

A complimentary problem to that of divergent student backgrounds also concerned the participants of the discussion groups reporting in Viewpoints on Undergraduate College Programs (Eiss, 1966b): "a danger of over-standardizing the curriculum, discouraging experimentation and innovation" (p. 65). It was observed, in fact, that there would be a need for flexibility within the curriculum of an institution. Eiss (1966b) went even so far as to say, "Much of the present college science curriculum is unsuitable for students' present and future needs" (p. 70). "Continual attention to the need for continued curriculum revision" (p. 65) was urged by the discussion groups. Eiss (1966b) reiterated this proposal in "Trends and Implications for Action in College Science Programs" (p. 69). Apparently, their plea was heeded, for many meetings have been convened (i.e., Baker, 1967) and papers written (i.e., Schein, 1967; Hertig, 1969; and, Frosch, 1973) on the topic curriculum revision, in the years that

followed.

In his article, "Toward a Third Century of Science Education," Bybee (1977) described the urgent need for reform in science education. He sites as reasons for the necessity of this reform the "contemporary trends and problems directly related to science and technology, . . . " (Bybee, 1977, p. 360). Bybee goes on to suggest a list of policies for consideration by the science education community.

- Reform of curriculum materials and instructional techniques should start at the elementary level and continue up to the secondary schools and finally to higher education.
  Initial efforts should concentrate in the areas of environmental, earth, and biological sciences.
- The curriculum should introduce scientific concepts fundamental to issues such as population growth, ecology, energy, technology, and economics.
- The programs should incorporate the goals of personal development and problem solving much more than they have in the past.
- Instructional programs should extend the students' perceptions concerning the environment from the present to the future; they should develop a concern for both the individual and humankind; and, problems should be understood as both isolated phenomena and complex interacting systems.
- Teaching should be personalized and emphasize elements of interpersonal and group dynamics.
- Instruction should encourage the development of values through the presentation of attitudes inherent in the scientific enterprise; the clarification of personal values; the consideration of ethical choices and the re-evaluation of one's own moral positions.
- Specific emphasis should be placed on the requirements of effective implementation of the new materials.

Bybee's suggestions for curriculum reform are certainly idealistic and open for debate (Baker, 1967; and, Kormondy, 1976), but there is little denying the impact of science and technology on science education (DuBridge, 1966; Eiss, 1966a; Hilberry, 1966; Neidig, 1966; and, Smith, 1966). Science and technology have so changed the environment in this country and, indeed, the world, that science education has had to adjust its focus to meet the new demands of a rapidly evolving society (Neidig, 1966; and, Bybee, 1977).

For the United States, the early 1960's were a transition period of immense importance. This country was experiencing the end of its "Age of Industrial Progress" (Bybee, 1977, p. 339), and the beginning of the Scientific Revolution. It was also experiencing an emerging awareness of the "negative trade-offs of technological development . . . " (p. 339). Bybee characterized this period as follows:

> There was suburban development with urban decay; corporate conglomerates increased and small business decreased; and we became an affluent society with new minorities of organizational men, lonely crowds and other Americans. By the 1960's almost every aspect of public policy, both domestic and foreign, was being severely criticized as the basic institutions including education were being called on to reform.
>
> By the middle of the 1960's . . . a new wave of educational critics appealed for a greater understanding of student alienation, identity, and self-concept. The focus in education had shifted from the space race to urban disgrace. By the 1970's we were told there was a Crisis in the Classroom (Silberman, 1970).

Bybee supports his observations by citing other authors, such as Carson (Silent Spring, 1962) and Meadows, et al. (Limits to Growth, 1972), who stressed that many of the contemporary crises were signaling the necessity for this country to make the transition from continual growth to living in harmony with an environment having a limited carrying capacity. Such a transition would obviously have enormous implications with respect to education, particularly science education (Hodgson, 1970). Science education would have the responsibility of educating and re-educating the public concerning ecological dynamics, including such topics as energy, pollution and limited resources management.

Bybee identified another type of transition that grew out of the social criticalness of the sixties and reached its apex in the seventies. The transition of our society from one of industrialization to a "post-industrial service oriented society" (Bybee, 1977, p. 357), was marked by a shift from an industrial technological economy towards one of increased human professional and technical services ("medical care, social welfare, technical services, and education" (p. 357)). Perhaps during the seventies the United States was moving toward "an economy of limited growth" (p. 358) as proposed by such economists as E.F. Schumacher (in Small Is Beautiful, 1973).

In the eighties, however, dramatic governmental cutbacks have either been proposed or already initiated in virtually all of the above-mentioned human professional and technical services. Consequently, education is caught in the crossfire between high inflation, rising costs and reduced governmental support, causing educators to take a long hard look at curriculum design and content in an effort to maximize the use of diminishing resources.

The public has also been acutely aware of the economic stress growing in this country. What began in the sixties as student demands for more "relevant" courses, electives and student input into course curriculum and design evolved into an era of consumerism in education (Carnegie, 1977). In the early sixties, the manpower needs of the country (i.e., the consequences of the space race), dominated curricular development. Today, however, dropping enrollments and stressed budgets have fueled an intense competition among institutions of higher education for students. Consequently, student preferences are having a tremendous impact on curricular development (Carnegie, 1977).

Finally, intimately related to the consumerism phenomenon is the increase in student diversity that has been growing during the last two decades. "Larger numbers of women, ethnic minorities, part-time, poorly skilled, foreign, and handicapped students are enrolled; while the

'non-traditional' students tend to be concentrated in disproportionate numbers in certain kinds of institutions, it is a rare school that has not been affected at all by this broadened base" (Gaff, 1980). In Missions of the College Curriculum (Carnegie, 1977), it is stated that the needs and preferences of these students have enormously influenced the evolution of education in this country, having resulted in the development of "extensive, varied, and, in some cases, flexible curricula" (p. 23). Since general biology is identified as a general education course, as well as an introductory course for biology majors, it is interesting to note that Hudson and Smith (1976) consider general education (in the California Community College System) as "a collection of courses that are unrelated, irrelevant, lacking in meaning and failing to meet the stated goals of general education" (p. 62).

Upon reviewing the historical background of education in the United States, for the last two decades, there is little doubt that both science education and general education have been profoundly changed. In his overview of the "Colloquium on Biology in a Liberal Education" held at Stanford University (August 2-13, 1965), Baker (1967) observed that the "[c]olloquium participants faced the fact that biology is a changed and changing discipline - that most of us were taught introductory biology courses

that would no longer be fully acceptable in terms of subject matter and/or approach" (p. 7 . Certainly, then, there is no doubt that general/introductory biology courses have undergone change in purpose and/or content. The remaining questions concern how general biology has evolved in the last two decades.

General Biology in the Last Two Decades

In the first part of this chapter, the forces inducing change in biological education were discussed. In this section, the changes that biological education, specifically general/introductory biology, has undergone will be discussed.

The Curriculum Revolution

The Impact of the Scientific Revolution. Frosch (1973) noted that science curricula had been in a "state of flux" (p. 1) through the sixties and into the seventies. This was certainly no less true for biological education. During those years the biological teaching community struggled to adjust to the impact of the knowledge explosion that was (and is) a consequence of the Scientific Revolution.

Schein (1967) identified several important trends that biological education was undergoing in the mid-1960's. The

following are elements of those trends pertinent to the evolution of courses in general biology: increasing emphasis on preparation in mathematics; increasing emphasis on the molecular and cellular levels of organization; the replacement of the phylogenetic ("traditional") approach, as an organizing principle for biology instruction, by heredity, cytology, developmental biology, mechanisms of integration, and evolutionary dynamics.

Some educators claimed that, "The initial changes in science curriculum were brought about by the development of new materials for use in the secondary schools [Hurd, 1962]" (Frosch, 1973, p. 1). By far, the most influential and widely used of those were the Biological Sciences Curriculum Study (BSCS) materials. Their use was nation-wide and reflected curriculum revisions in secondary biological education at a national level. However, at the 1965 Stanford Colloquium on "Biology in a Liberal Education" (Baker, 1967) several alternative perspectives on the BSCS series were offered:

> It was pointed out that the impact of BSCS materials had not yet been felt at the college level. However, some individuals had taught students who had taken BSCS biology and said they found little difference between them and students who had taken other courses. Two persons stated that their BSCS students recalled certain key terms or phrases of modern biology (such as DNA or RNA), but demonstrated either superficial or incorrect information concerning them. These persons would have preferred the students not to have had such biology, feeling that "there is nothing harder to teach a student than something he thinks he already knows" (pp. 8-9).

It seems more likely that curriculum revision in college biological education was primarily a direct response to the revolutionary changes that the discipline of biological sciences underwent (Schein, 1967).

> Whatever problems contemporary biological education faces, they are primarily the result of the success and expansion of the field as an academic discipline. New methods, new information, and new problems, all have eroded away the central elements which characterize the earlier systems of thought, and our teaching of biology must mirror these changes (Baker, 1967, p. 7).

Two influences of the Scientific Revolution that seem to have been identified as being the most important to curriculum revision in college biological education: the impact of molecular biology and the sheer enormity of the resulting amounts of information. One effect that these two factors have had on general/introductory biology courses have been the "selective filtration" (Baker, 1967, p. 13) of their content. A participant of the 1965 Stanford Colloquium described the phenomenon as follows:

> There is one thing that especially impresses me about the teaching of biology today. This is the rapidity in which the molecular revolution in biology has forced us to cull out the dead wood of biology. Perhaps biologists should be grateful for this, not resentful, for rarely has any field progressed as rapidly. Yet suddenly we are faced with an heretical idea - that we cannot retain even a survey of the representatives of the great animal and plant phyla (Harvard sends its students to the museum during Chrismas vacation), or that we cannot describe the organization and functional attributes of the vertebrate or the angiosperm, because all new contributions to molecular biology must be inserted automatically as they occur (Baker, 1967, pp. 13-14).

This phenomenon has been identified as a transition from "traditional biology" to the "new biology" (Baker, 1967).

A second important impact of molecular biology and the "knowledge explosion" (Postlethwait, Novak and Murray, 1969) on introductory biology courses was the propagation of various organization schemes. These strategies have been categorized into two groups: (1) "the selection of content based on adherence to a theme" (Baker, 1967, p. 15), and (2) "mode of presentation of material" (p. 15). Some of the most important course organization schemes applied to general/introductory biology courses have been:

1) The "inquiry" approach.[1]
2) The "scientific method" theme.
3) The "evolution" approach.
4) The "whole organism" theme.
5) The "organismal-environmental" complex.
6) The "themeless" course.
7) The "paperback" course (pp. 15-20).

The inquiry approach evolved out of the work of Bruner (1961 and 1966), Gagne (1963) and their colleagues on "discovery" learning (Suchman, 1966; Shulman, 1968; Burns and Ellis, 1970; and, Frosch, 1973). Bruner, who is most

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[1]Of the seven organization schemes described, Baker (1967) seems to imply that the inquiry approach received the strongest support among the participants of the 1965 Stanford Colloquium on "Biology in a Liberal Education."

closely identified with discovery learning, proposed that discovery rarely occurs outside of the learner. Instead, "discovery is the act of reorganizing previously learned facts to produce a better fit between these facts and the regularity with which they will be encountered in the learner's experience" (Frosch, 1973, p. 7). Inquiry learning is distinguished from learning by discovery in that the latter is governed by controlled procedures leading to predicted results; whereas the former is relatively unrestricted. In inquiry learning, the instructor functions primarily as a response person and a source of encouragement (Connelly, 1969; and, Frosch, 1973).

Shortly after its introduction, many educators and scientists proposed that the inquiry approach be incorporated into the curriculum so as to form a learning pattern (Gagne,1963). However, this enthusiasm was also accompanied by considerable confusion of inquiry learning with discovery learning (Lee, 1970; and, Frosch, 1973). In addition, Lee (1970) reported that many college science faculty employ inquiry learning only in the laboratory. He observed that they did not or could not utilize it in classroom instruction. However, many other college instructors have reported successful application of the inquiry approach in the classroom (Baker, 1967). Their support of the method is reflected in a statement written by one of the Stanford Colloquium participants:

> I agree with Conant and others that the best way to display the nature of science is to drop the novice into an intimate position in the activity itself - to apprentice the novice to a scientist - the "you can't learn to swim without getting wet" school. There is no need here to go into the considerations that would render this ideal very nearly impossible. There is, however, one point in the actual biological enterprise with which the students can be realistically related. This point is the literature of science. I refer here to the real literature, not the stuff of textbooks, although on rare occasions real literature has been written in the textbook form. Textbooks, in fact, appear to me to be written from a position of total misunderstanding or lack of comprehension of the meanings and proper goals of the educational endeavor (Baker, 1967, p. 16).

It should be noted that biological education has been impacted by advances in educational psychology in ways other than inquiry learning. The use of instructional objectives has slowly gained acceptance. However, there are problems to their application, as mentioned by Erickson (1970):

> Clear-cut behavioral objectives are difficult to define for most college-level course. How . . . can the instruction and evaluation be adjusted to encompass the subtle objectives of motivation to learn, critical thinking, value judgement, favorable attitudes toward the discipline, ability to organize relevant information and to solve problems, etc.? (p. 17).

The evaluation and organization of course curricula in terms of classification strategies such as those of Bloom (1956) and his predecessors has greatly facilitated the use of instructional objectives in general/introductory biology courses.

The scientific method theme is interrelated with the inquiry approach, resulting in "a course theme based on the student's early and sustained exposure to the logical basis of scientific methodology" (Baker, 1967, p. 16). The literature seems to suggest that this method was slow to be adopted. Initially, there was a shortage of text materials utilizing this instructional technique. Also, there was some criticism of the approach. Some pragmatists expressed the concern that students might receive an overly rigid perspective of scientific methodology, stressing "the necessity of the student's awareness that much of the logical scientific framework applied to experiments fits far more nicely after the work is done than before" (Baker, 1967, p. 16). Acknowledging the pitfalls of the approach, supporters of the scientific method approach actively maintained that the problems "could be circumvented through continued emphasis on the deductive nature of scientific experimentation and avoidance of the false pretense that the research scientist's original reasoning processes were being created" (Baker, 1967, p. 16). With the ever-expanding frontiers of computer science and multivariate statistics, the inductive approach to biological research is replacing the deductive approach. Thus, it can be expected that the scientific method approach will be studied from more of a historical standpoint than a utilitarian one.

The evolution approach can best be described in the words of a Stanford Colloquium participant:

> If there is any one major idea or concept of biology which serves to unify the field, it is most probably that of organic evolution as presently understood. Accordingly, it would seem proper that any introductory course in biology should not only include this concept as part of its body of material, but also make every attempt to interweave it throughout the course as a unifying thread (Baker, 1967, p. 17).

The whole organism theme has been described as follows:

> The course would concern itself mainly with the broad generalizations of biology but would include as illustrations a consideration of additional concepts strictly plant or animal. It would be oriented toward the living organism with excursions to the molecular and biosphere level as these are needed for knowledge and understanding (Baker, 1967, p. 17).

This mode of teaching was influenced by the "synergistic" approach generated by the ecological movement in biology. The literature seems to indicate that it has received little acceptance.

A general/introductory biology course employing the organismal-environment complex mode of instruction is designed to "'acquaint the student with our present level of understanding of biotic phenomena, and introduce him/her to the processes of method and logic through which this current level of comprehension has been attained'" (Baker, 1967, p. 17). The key to this instructional approach is the concept of <u>adaptation</u>. A promoter of this mode of instruction supported his case with the following statement:

> . . . Adaptation . . . may be effectively employed as the basic frame of reference within which nearly all biotic activities or attributes may be meaningfully interpreted. Adaptation may in fact represent the most unique and universal attribute of life. Hence the concept of adaptation may well be the central phenomenal principle in biology (Baker, 1967, p. 17).

The themeless course is an instructional approach reflecting the belief that any unifying theme is much more obvious to an instructor than the students of a general/introductory biology course (Baker, 1967). Another argument against a thematic approach to general/introductory biology was that emphasizing one theme "fails to develop a true understanding of the scope and importance of modern biology" (Baker, 1967, p. 19).

Finally, the paperback course is an instructional technique that substitutes textbooks with carefully selected paperbacks. This type of course is designed for both majors and non-majors, and individual participation on the part of the student in research is used as a teaching device for the more advanced and/or talented students (Baker, 1967).

In addition to the seven approaches discussed above, an eighth course organization scheme was developed to cope with the over-abundance of biological information - the "'in depth approach'" (Kormondy, 1972, p. 8). Supporters of this approach felt that it was no longer possible to cover all of modern biology in a one-year course, let alone

in a one semester course. It was recommended, therefore, that certain key topics in biology be selected at the discretion of the individual instructor and taught in greater detail.

It should be noted that there was significant resistance to the impact of molecular biology was having on biological education in the sixties. Some educators felt that many of the new instructional approaches to introductory biology placed too heavy of an emphasis on the molecular, while not giving enough attention to the whole organism and its environment (Baker, 1967). Other educators in biology felt that as a result of the new emphasis on molecular biology, the student was being cheated of "the beauty inherent ot the living state as it exists in nature" (Baker, 1967, p. 37). However, the spirit of such dissention seemed to be largely a resistance to "'change for the sake of change'" (Baker, 1967, p. 37). Schein (1967) suggests that there is some substance in this concern, and emphasizes that "[t]he basic criterion for inclusion or exclusion [of instructional content] is not recency but significance" (p. 28).

As mentioned earlier, educators and scientists were struggling, in the mid-1960's, with the problem of how to fit all the relevant information being generated by the Scientific Revolution into a one-year curriculum. As a

consequence, one participant of the Stanford Colloquium suggested the following for liberal education programs:

> One approach might require two years, enrollment from both sciences and the humanities, and most certainly include a lab. It might begin with mathematics, move into physics, then chemistry, and finally biology, providing a truly integrated approach (Baker, 1967, p. 21).

The same individual continued to describe his suggestion in the following discussion:

> The integration of the new biology into traditional biology seems to result in a subject with a logical sequence beginning with considerations of energy, organelles, cells and tissues, and then to organisms and populations. It is noted that traditional biology deals largely with the latter of these while the new biology is concerned more with the former. Thus if we are to follow rule (2) of Professor Schmidt we must teach the new biology first and then lead into the traditional areas. This apparently, is the reverse of the usual procedure. Using genetics as an example, we observe that students are usually taught Mendel's Laws first, chromosome or cytological genetics as an example, and finally, are told about DNA and RNA and shown how the linear arrangement of information in nucleotide sequences and the various gyrations of the DNA and RNA molecules can 'explain' observed genetic phenomena. According to the plan being investigated here, the molecules would come first, their gyrations and chromosomes second, and then, probably with some historical flavor, the observable genetic consequences of the molecular aspects (p. 22).

Another implication of the knowledge explosion of the Scientific Revolution was the question of how to include at least some elements of the history, philosophy and sociology of science in a general/introductory biology course. Many educators and scientists in the mid-sixties felt that these perspectives were indispensible to any course purported to

be introducing the science of biology. A Stanford Colloquium participant observed:

> . . . biology as a science is evolving, and has continuity, with its present rooted in the past. Great theories and great insights arose from complex events, and the future can be speculated upon best with these insights. Therefore, an historical perspective is desirable (Baker, 1967, p. 23).

Prior to the Stanford Colloquium on "Biology in a Liberal Education," the "case history" approach (Harvard Committee, 1945) was used to include the history, philosophy and sociology of science. However, a number of criticisms were directed against it (Baker, 1967). First, it was argued that this course design taught about science, but did not teach science. Second, most such courses were regarded as hybrid, and thus, considered incapable of serving the purposes of science nor history, philosophy and sociology. Consequently, by the mid-1960's, almost all the general/introductory biology courses, which had taught the case study approach, returned to teaching "straight science" (Baker, 1967, p. 25).

An alternative to the case study approach, arising out of the Stanford Colloquium, was a proposal that introductory biology be taught as a "double-track" program (Baker, 1967, p. 24). The proponent of this idea gave the following explanation:

> . . . it is proposed that the student take two courses simultaneously: one in a science (in the case discussed here, biology), and one in the general history

> of science. The course in introductory biology would be rigorously organized and taught by a biologist. It is hoped that the biologist and the historian of science would review and discuss each other's course outline as much as possible. It should be emphasized, however, that the overriding concern of the biology course should be the teaching of biology (Baker, 1967, p. 24).

The Question of Relevance. The effects of the Scientific Revolution broadened and intensified with the close of the sixties and entrance into the seventies. There was widespread concern among biologists and educators over the effects of "reductionism" (Hodgson, 1970) on biological curriculum and over the question of social responsibility on the part of biological education (Baker, 1967; Hodgson, 1970; and, Lee, 1971).

The term reductionism was applied (by some critics) to the phenomenon of over-emphasis of molecular and cellular biology in biological education (Koestler and Smythies, 1969). In response to reductionism, scientists and educators began to call for a "return to relevance and to a concern for the inter-connectiveness of knowledge" (Heiss, 1968, pp. 32-33). However, their motivation to revamp biological education was certainly fueled by the growing dissatisfaction of the students and other critics. In response to students' "cry for relevance" (Lee, 1971, p. 81), the development of teaching technology was greatly accelerated. The next decade was marked by the rapid

proliferation of teaching innovations.

The social unrest of the sixties and seventies was accompanied by a growing polarization between the scientists and non-scientists (Hodgson, 1968). C.P. Snow attributed the gap between the two groups to the failure of scientists to deal adequately with the chief perils threatening mankind (i.e., overpopulation, the disparity between the "haves" and the "have nots," and nuclear war). In particular, Laetsch (1967) accused college biology instructors of failing in their responsibility to raise student awareness of the role biology must play in coping with contemporary global problems. Heiss (1968) also observed:

> Students and other critics are more and more prone to raise important moral questions regarding the character and ultimate use of the knowledge discovered by scholars and disseminated by their academies . . . In particular they express impatience with the lag between theory and practice - especially when the practice involves the resolution of a pressing human problem.
>
> Student unrest provided the imperatives for this reexamination . . . (p. 3).

In order to bridge this gap, biologists and educators began to demonstrate "a concern with the social applications of biological discoveries" (Hodgson, 1970, p. 11). The issue of the social responsibility of an introductory biology instructor was discussed at the Stanford Colloquium (1965) with considerable debate. Many participants were strongly in favor of the instructor's responsibility to

"emphasize the social implications of science in general, and biology in particular:

> The purpose of our schools is the development of free, capable, and responsible individuals aware of something beyond their desks or benches . . . within themselves, within their homes, within their society, and ultimately, within the nature of the universe. At the heart of our system of higher education is the liberal arts college. It is here that we expect our future leaders to acquire the perspective, the insight, and the ability to communicate that will enable them to become the catalyzers and the binders of an open society. The teacher of undergraduates must therefore be more than a specialized scholar; he must himself possess the general skills and exemplify the values he is responsible for transmitting. There will always be those who will not acquire a wider view and sense of responsibility commensurate with their achievement in specialized tasks, and there will be those who do not have the ability or the will to achieve mastery in some endeavor, but an increasingly high proportion of the educated must possess both breath and depth if we are to avoid being ruled by technicians and demagogues (Baker, 1967, pp. 30-31).

Many other participants, though, felt that the biology instructor should <u>not</u> be involved in presenting the social implications of biology to his/her students. Probably, the most outspoken educator concerning this issue was Dr. Paul Weiss, of the Yale University Department of Philosophy. He argued that "the instructor's only responsibility was to teach good, up-to-date biology, and that the constant attempt to show the utilitarian justification for a particular area was, in a very real sense, an attempt to justify its existence - to apologize for it, so to speak" (Baker, 1967, p. 32). However, pressure from students and other critics overcame this resistance, and by the 1970's,

biological education, including general and introductory biology, increasingly emphasized concern for the problems of biology and society.

As discussed in the "Historical Overview", in the late sixties and early seventies, large numbers of students and young people were involved in social activism. They were concerned with biological, social and political questions. However, with the conclusion of the Viet Nam Conflict, student interest and involvement in these issues waned. Kieffer (1979) cites the following reasons for this decline:

> 1. The present generation of students has grown up with many of these problems and has become immune to their ramifications.
> 2. Students' interest in idealistic values has declined and been superceded by a growing interest in materialistic goals including wealth, security and status.
> 3. Students are disillusioned; when their attempts to correct the flaws in society met little or even negative success, they dropped out, adopting a "the system is too big to change" attitude.
> 4. Finally, many people refuse to believe that our society has problems. In their view, we - as individuals and as a society - are really quite well-off, and if things are not getting better and quickly as we would like, certainly they are not getting worse (p. 176).

Most of the threats to our society have not diminished and therefore, the social responsibility of the general/introductory biology instructor has not decreased. Today, the instructor must not only attempt to raise the awareness of students with respect to the impact of biology on society, but he/she must attempt to raise their level of

concern as well. As a by-product of these emphases, it is hoped the level of public negativism toward science (Dean, 1970), that intensified during the late sixties and early seventies, will be decreased.

The "cry for relevance" that started in the late sixties has continued until the present. However, its emphasis is no longer socio-political, but utilitarian. Higher education is in a well-publicized period of dropping enrollments and reduced funding (Dean, 1978). Consequently, it has been increasingly influenced by student "consumerism" (Missions, 1977, p. 2), as mentioned earlier in this paper.

In response to present economic conditions, students have tended to select career goals based primarily on financial promise. While student enrollments in such fields as engineering and computer science has stabilized or continued to increase, enrollment of students in biology has generally decreased. In most schools, the decrease in enrollment has necessitated the reduction of sections offered for many biology courses. In many instances, it has resulted in the reduction of course offerings and/or the reorganization of biology curricula. Hence, most colleges are unable to offer general/introductory biology courses for both biology majors and non-majors.

Dean (1978) identified, however, another important implication of decreasing enrollment:

> In short, nonmajors who have too often been unidentified fillers in courses designed for someone else are likely to become very welcome additions to our biology classes (p. 564).

Major versus Non-Major. As was implied in the previous section, there was some discussion over whether separate general/introductory biology courses should be offered for majors and non-majors (Baker, 1967). In the mid-1960's, a Commission on Undergraduate Education in the Biological Sciences Panel determined that only one course should be taught for both biology majors and non-majors. The Panel gave the following reasons for its decision:

> 1) When a separate course for nonmajors exist side-by-side with a course for majors, the former often becomes a watered down version of the latter.
> 2) Should a student in a nonmajors course become interested and wish to become a biology major he must then take the introductory course for majors in his sophomore year.
> 3) Many small colleges simply do not have the staff or facilities to offer two different introductory courses (Kormondy, 1972, p. 7).

The decision of the Panel was confirmed by most of the participants of the Stanford Colloquium. However, many of these individuals saw the need for revisions of existing introductory biology courses. And, many of these instructors felt that the non-major should not be exposed to course content traditionally given to the major; nor should the major student be exposed to the more specialized information (i.e., that of molecular and cellular biology), that was infiltrating general/introductory biology courses.

Instead, it was proposed that both majors and non-majors receive a new course "designed to impart an overview of the field and its vast potential for intellectual growth and achievement, to the non-major for his continuing appreciation of the discipline, and to the major for his participation in it" (Baker, 1967, p. 34). Mayer (1968) echoed this call for reform by stating that there was a critical need for re-examination of biological education in terms of its philosophy, content and methodology.

In the early 1970's, general/introductory biology, in most cases continued to be offered as a majors'/non-majors' course (Shamous, 1970; and, Frosch, 1973). One justification offered by some educators at the time was that equal treatment of both groups of students was the best way to develop an appreciation for a scientific discipline (Frosch, 1973). In addition, some educators continued to express concern that an introductory biology course designed specifically for non-majors might become a diluted version of the course for biology majors (Hankins, 1970; and, Frosch, 1973). Frosch (1973), in her survey of the literature on the subject, claimed that "[a] majority of scientists and educators . . . accept the idea of separate classes for the two groups" (p. 19).

Curricular Revision. The call for revision in general/introductory biology continued into the seventies.

Educators noticed that general/introductory biology students were bored and restless (Blazier, 1971; and, Frosch, 1973). Most instructors interpreted the problem as a need for curriculum reform (Nisbet and Mertens, 1971). Certainly, biological education had undergone massive change, as a consequence of such forces as the knowledge explosion (Postlethwait, 1963), student pressure, curriculum revisions at other educational levels, and a shift in emphasis (Hardin, 1970; and, Frosch, 1973). However, numerous criticisms of biology continued to be levied against the discipline suggesting the need for further reform. For instance, college faculty were criticized for building their biology courses around adopted textbooks (Hutto, 1965). It was argued that, because of the great diversity among textbooks (from simple to complex; from cellular emphasis to ecological emphasis), a course might change as the textbook changes without consideration to student needs. Frosch (1973) reasoned, "What seems to be needed in the curriculum effort to revise the biology curriculum is organization and direction" (p. 15).

Haskin (1970) alleged that Ph.D. professors compromised their responsibility to the teaching of their general/introductory biology courses for the sake of research. She further alleged that, as a result, the quality of teaching in general/introductory biology courses was very questionable. Dunham (1969), in his study of

American colleges and universities, supported Haskin's observations.

General/introductory biology laboratory instruction came under attack as well. Hutto (1965) maintained that there were an excessive number of demonstrations and dissections, and an insufficient number of opportunities for student participation in "true scientific investigation" (Frosch, 1973, p. 16). Dean (1969) proposed a similar criticism when he asserted that the weakness of many introductory biology laboratory curriculum was the overemphasis on fact memorization. As an alternative, Butts (1965) proposed that the emphasis be on the search for basic principles.

Many college biology instructors have expressed the opinion that the choice of course content for general/introductory biology courses should expose the student to the immense scope of biology. Simultaneously, those course content choices should raise his/her awareness of the investigative nature of biology (CUEBS, 1967). In addition, Scherba (1967) proposed that course topics should be selected on the basis of their contribution to student understanding of basic biological principles. Finally, Frosch (1973) emphasized that the more esoteric aspects (attitudes, decisions, strengths and limitations, and values) of biology must be presented in a general/introductory biology course, if the course is to be useful

to the student. This same point was emphasized by CUEBS, with respect to the biology laboratory experience, in a 1969 report entitled, Investigative Laboratory Program in Biology (Kormondy, 1972).

Within the last two decades, many plans have been proposed for the restructuring of general/introductory biology courses. Based on the results of a survey performed in the early sixties, the Commission on Undergraduate Education in Biological Sciences (1967) compiled the following list of potential topics appropriate to a course in general/ introductory biology:

1. The history of life.
2. Natural variation.
3. The nature of genetic continuity.
4. Molecular nature of life processes.
5. Biological holism and reductionism.
6. Homeostasis at all levels.
7. Environment-organism interactions.
8. Biological basis for behavior.
9. The species concept.
10. Dynamics of biological population and ecosystems.
12. Human population problems.
13. Conservation of natural resources.
14. Sound attitudes toward public health and medicine (Frosch, 1973, pp. 18-19).

In the mid-1960's, Roos (1965) proposed several plans which could be followed in renovating an introductory course in biology:

1. A survey of the entire body of facts understood to be included within the discipline and to create a set of predictive general conclusions.

2. An introduction to subjects in selected 'core' areas that will be further developed in advanced courses.

3. An examination in depth of limited portions of the total subject area.

4. A discussion of a set of concepts common throughout the discipline or necessary to its further study (p. 524).

Walbesser (1966) asserted that decisions in the choice of course topics from course domains could be generated by answering the following questions:

1. What big ideas from this discipline should be chosen?

2. What particular topics are fundamental to an understanding of the discipline?

3. What particular facts must an individual know if he is to appreciate the significance of this discipline? (p. 34).

Dressel (1968) maintained that "if concern for individual students is an important part of a program development then objectives should emphasize the growth and development of the individual" (Frosch, 1973, p. 142). After having investigated alternate methods for teaching large sections of general biology, Bell (1970) found that a variety of instructional methods and techniques had no apparent impact

on student achievement and attitude.

In the early seventies, the "survey" approach to teaching general/introductory biology was popular, such that, the greatest amount of emphasis was placed on course concepts (Frosch, 1973). However, Dean (1970) questioned its value in leading the student to "a better understanding of the role of imagination in scientific discovery" (Frosch, 1973, p. 16). Dean (1970) supported his doubts with two major criticisms of the science survey approach:

1. A survey of the content of a science too often fails to convey the true nature of science . . . science as quest.

2. There is no best content; and the search for it has diverted our attention [from] other, urgent aspects of our teaching (p. 524).

Also in the early seventies, Frosch (1973) observed that the inquiry method of teaching science is increasing. However, she also cited evidence that the lecture method was still the most popular (and perhaps the most successful), for teaching general/introductory biology classes. Thus, Frosch (1973) proposed a "hybrid" general/introductory biology course which would be taught using the inquiry, lecture and individual study approaches. Affective goals were emphasized as much as cognitive goals in her model. It was a synthesis of the best ideas at that time:

I. Statement of the general biology course objectives.

II. Statement of behavioral objectives both for the classroom and the laboratory.

III. Select or devise laboratory experiments designed to increase the student's skill in scientific processes (observations, measurement, formulating hypothesis, etc.). The laboratory should also provide the kind of environment which stimulates student curiosity and encourages scientific investigation.

IV. Coordinate the laboratory with classroom lectures.

V. Develop audio-tutorial lessons and module unit for biological areas in which only some of the students are unprepared (example, chemistry, basic measurement).

VI. Set aside an area near the laboratory which contains reference tests, 8 mm slide projectors and tables for student conferences and study (Frosch, 1973, p. 142).

Innovations. In the last two decades many teaching innovations, some at the strategic level, but most at the tactical level of instruction, have been applied to general/introductory biology courses. The primary motivation for their development has been the growing realization that human beings differ in receptivity to different approaches to a subject (Postlethwait, Novak and Murray, 1969; and, Frosch, 1973). Thus, many of those innovations have been attempts to effect some measure of individualized instruction in general/introductory biology courses.

The audio-tutorial approach was one of the earliest attempts to individualize instruction in general/introductory biology courses, and is still widely used

today. Diamond (1968) reported using a series of programmed booklets, 8 mm cartridge films, and 35 mm slides in teaching the laboratory portion of a one semester biology course for non-science majors. The results of this experiment in the independent learning approach to laboratory instruction bore considerable success. Arnwine and Juby (1969) reported greater than predicted success with their method. They used audio-tutorial stations where cassette tapes were used by the students in substitution for class lectures and to help integrate laboratory experiences with lecture material. The laboratory experience included various chemical experiments, slides, drawings, and living and preserved materials. The course was comprised of a series of instructional units which included behavioral objectives and exercises along with the tapes and visual aids. In addition, the students met in small groups with the instructor for two one-hour sessions per week.

The audio-tutorial approach of Arnwine and Juby contains elements of the modular approach to individualized instruction. Developed in the sixties (CUEBS Publication 31, 1971), it was seen as a potential means of bringing about needed changes in curriculum structure (Frosch, 1973). Modularization has been incorporated not only in audio-tutorial instruction, but also in computer-assisted instruction and traditionally more rigorous general/

introductory biology courses. Frosch (1973) envisioned modules as helping "the student master skills, change attitudes and learn concepts . . . " (p. 21).

Probably the newest innovation to general/introductory biology instruction is "computer-assisted instruction (CAI). Although developed in the 1950's (Alpert and Bitzer, 1969; and, Ayers, 1980), it is still very much a frontier in education, and there is considerable evidence that CAI can achieve an individualized instruction (Haser, et al., 1977; and Hofstetter, 1980). Early CAI programs were administered through time-sharing systems. Probably the most famous and most sophisticated of these systems is PLATO (Programmed Logic for Automatic Teaching Operations), developed at the University of Illinois (Magidson, 1974a). Magidson (1974a) reported a number of benefits derived by students using the system as with other CAI systems: 1) it permits each student to learn at his/her own pace; 2) it can provide immediate and precise feedback, and remedial or advanced work depending on the student's performance; and, 3) it provides the student with personal attention. In addition, it exhibits considerable flexibility, including serving as text, tutor and test. Magidson (1974b) later described the application of mastery learning principles in PLATO instructional units.

Manteuffel (1976) described extensive implementation of PLATO in biological education (including general/ introductory biology). Hofstetter (1980) in discussing the "Overall Educational Value of PLATO for the University of Delaware" lists a number of benefits, including the following relating to student attitudes and learning:

1. Individualized instruction.

3. Reduces time needed for instruction.

4. Emphasizes the intrinsic joy of learning and deemphasizes competition with peers as a motivating force.

5. . . . [E]nables students to develop a richer intuitive grasp of complex phenomena through graphic visual representation.

6. Provides students with access to a wide range of data for checking out hypotheses.

7. Enables students to learn more of the complexities of phenomena through modeling and simulation.

8. Encourages students to tailor their learning experiences to meet their own objectives.

9. Gives immediate feedback.

10. Provides students with an anonymous way of asking questions about sensitive matters.

11. Provides maximum flexibility (pp. 123-125).

However, microcomputers are rapidly eclipsing time-sharing systems, with respect to educational applications. They are reputed to be much less costly and even more flexible.

The Laboratory Experience. As shown earlier, most educators and scientists have indicated that a laboratory should be part of an introductory biology course. In fact, in the third National Society for Science Education Yearbook, Rethinking Science Education, it was stated, "All science-teaching is, to some extent, laboratory teaching" (Henry, 1960, p. 246). Also, "[T]here was virtually unanimous agreement among the Stanford Colloquium participants that laboratory experience was the most important part of any general/introductory biology course" (Baker, 1967, p. 26). However, there has been much criticism of the customary type of laboratory exercises which have been frequently found in college introductory biology courses (CUEBS, 1967; and, Frosch, 1973). The 1967 CUEBS Report (Baker) entitled, "Biology in a Liberal Education" listed several observations and suggestions (p. 28) with regard to those criticisms:

> 1) Familiarity (with varying degrees of sophistication) with many of the tools of biology - the microscope, microtome, respirometers and/or manometers, stimulators, physiograph or kymograph (via X-ray film or detectors), anaethesia, scalpels, titrations, pH meters, spectrophotometers, growth chambers, analytical balances, centrifuges, etc.

This emphasis on scientific instrumentation was justified with the argument that the main thrust of the Scientific Revolution has been a consequence of the technological revolution.

2) Maximum use of live materials. Thus, fertilization and cleavage should be observed using live sea urchins, e.g., not prepared slides, although slides may be made available for comparison and for observing later stages.

3) Completion of experiments. Experiments should work to a reasonable degree so that students can get some results and begin to learn some skills.

4) Prompt presentation of an exciting,openended situation during the first or second meeting, preferably. A live plant or animal which can react to various stimuli in a measurable way would be the most ideal experience.

5) Inclusion of certain concepts of measurement using biological materials.

6) Coordination of laboratory sessions with the lectures.

7) Use of small reading room with books and reprints. From the reprints found here, the reading assignments are given. While the college libraries also do this, its more valuable role would be to provide a way for the student to be casually exposed to a much wider range of books. The shelves would contain popular introductory tests, a few good introductory books in chemistry, physics, mathematics, and sociology, fiction about biology (including science fiction), biological classics which instructors never have a chance to assign, back copies of Scientific American, molecular models, books related to social concern in areas of biology, and, where feasible, duplicated copies of pertinent research literature.

8) Avoidance of over-emphasis on lab reports and drawings. Students should use a drawing as a personal thing to make his own recall easier. There are courses for drafting and lettering . . . this is not one of them.

In the 1969 CUEBS Report, Investigative Laboratory Program in Biology (Kormondy, 1972), several roles traditionally assigned to the laboratory were listed:

1) the illustration of objects and experiments that have been introduced elsewhere in the course;

2) the provision of training in laboratory techniques;

3) the intellectual stimulation of the student and the development of an appreciation for biology and for living things; and,

4) the creation of an environment for a discussion of the many facts and ideas that arise from working with organisms and experiments (p. 11).

However, the report indicated that the most important role of the laboratory "is to engage the student in scientific investigation" (Kormondy, 1972, p. 11). The following are the syllogistics that resulted in this conclusion:

1) [T]he investigative origin and rapid rate of change of biological knowledge make it essential that biologists stress the process by which the content of our discipline is generated and changed.

2) [S]cience curricula should be planned to provide for increasingly complex inquiry activities as students progress from elementary school to college.

3) [I]nvestigation provides considerable possibilities for individualizing instruction.

4) [I]nvestigation provides the opportunity to develop creative and critical abilities in complement to the powers of comprehension and memory stressed by traditional content-oriented pedagogy (Kormondy, 1972, p. 11).

The CUEBS reaffirmed the objectives it assigned to laboratory instruction in its 1969 report and in a 1972 report entitled, <u>The Laboratory: A Place to Investigate</u>.

General/Introductory Biology in the 1980's

Information on the status of college general/introductory biology courses in the eighties is understandably scarce, because of its recency. What little information is available is sometimes confusing. For instance, major findings from a national needs assessment report of science education in two-year colleges (Hodes, 1980) included:

> · Most science fields . . . are perceived to be in critical need of [educational] improvement (p. 7-5).

and also,

> · There is no significant indication of need for revising course content or curriculum structure for existing science programs [including general/introductory biology] in two-year colleges (p. 7-7).

However, one finding of this study that is not shrouded in ambiguity is:

> · A substantial proportion of science students in two-year colleges lacks adequate language, study and math skills (p. 7-15).

The fact that many students enter colleges of all types, but particularly community colleges, without skills considered necessary for college academics is generally acknowledged (Hodes, 1980). The administrators and faculty that participated in this study ranked language skills as a primary problem among science students. If course content and design remain unchanged, it would seem likely

that achievement levels of students in general/introductory biology courses would not increase. Such a retardation of student achievement is presently being experienced. Its implications, with regards to the design and content of general/introductory biology courses deserve close attention.

CHAPTER THREE

Summary, Conclusions and Recommendations

Since the early sixties, general/introductory biology courses have evolved as a consequence of a multitude of forces, some tremendous, others more subtle, all of which have been changing the face of our society, in general. These forces are, in turn, consequences of a much greater phenomenon, the Scientific Revolution.

The Post-Industrial Era was heralded by the technology explosion, which resulted in widespread shortages of scientists, engineers and high technology craftsmen. These shortages and the national fervor generated by the space race aroused the educational community to meet this demand.

The involvement of the United States in the space race, and other forms of international socio-political competition, demanded an enormous investment of national resources, and the consequential support of the American public. The scientific community soon realized that public understanding of scientific developments was essential to continued public support. Scientific literacy was therefore promoted in education.

The technology explosion affected general/introductory courses in an even more direct manner, by accelerating the development of molecular and cellular biology, resulting in a knowledge explosion in biological sciences.

By the mid-1960's, a cry against the negative effects of the Industrial and Scientific Revolutions was rising from the non-science/technology community. A demand for quality of life over quantity was expressed. A subsequent polarization between science/technology and the lay community developed, underscoring the urgency of the promotion of scientific literacy by science education.

Simultaneous with the social activism of the sixties was a "cry for relevance" by students and other critics. Students became outspoken and even militant. They demanded that science become more responsible in addressing world problems and that science education be more responsive to their individual needs. Although student activism diminished after the close of the Viet Nam Conflict, student consumerism has continued to grow as student values have continued to become more utilitarian.

The developments described above, as well as many other factors, have contributed to the curriculum revolution, characterized by the intense level of curriculum revision and development of the last two decades. With respect to general/introductory biology courses, there has

been a considerable proliferation of instructional strategies and course organization schemes. General/introductory courses have been the beneficiaries of many of the products of teaching technology, the development of which was accelerated as a consequence of the Scientific Revolution. In response to the call for a greater degree of individualized instruction, such innovations as audio-tutorial instruction, mastery learning and computer-assisted instruction have been employed in general/introductory biology courses.

Future advances toward individualized instruction in general/introductory biology courses will be challenging indeed. Student enrollment in biology curriculum is generally declining. Hence, nonscience majors are comprising an increasingly larger proportion of general/introductory biology courses. Pressure on the instructors of those courses to make them relevant to the goals of nonscience students has consequently been increasing. However, considering prospective reductions in funding, the future of such educational advances seems dim.

The tide of public apathy toward education must be turned. There must be a renewed national commitment to education, in particular, general education, including general/introductory biology courses. Simultaneously, efforts within education toward curricular reform in

response to student needs, must be continued. Specifically, the following recommendations (Kridel, 1980) should be employed to facilitate this process of renovation:

* Professional educators must endeavor to be more acquainted with curriculum knowledge and with those involved in curricular reform.
* Greater communication and cooperation between general education at the secondary-school level and that of the college and university must be instituted.
* Serious efforts in curriculum research and experimentation must be incorporated into general education reform.
* The results of research in curriculum theory should be applied more fully in efforts toward general education reform.

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